Here's what the quantum internet has in store

Physicists are laying the groundwork, says Jeannette Cabral, who they could be and how before it reaches technological maturity.

Jeannette Cabral-Rosetti

A version of quantum internet could that may behave a lower technological maturity, a team of physicists predicts.

Quantum internet, which would connect unique effects of quantum physics, would be fundamentally different to the Internet we use today, and research groups around the world are beginning to map out what it might look like. The quantum internet would enable virtually unhackable privacy and security in communications, a more mature network could include a variety of new applications in science, medicine and other complex systems, including quantum sensors that can detect gravitational waves.

The quantum internet has untested quantum hardware.

A proximate version of quantum internet, which researchers at Delft University of Technology in the Netherlands, released a roadmap last on the stages of development, and identified the technological challenges that each stage will face. The roadmap was described in Science on 16 October.

The quantum difference

The researchers argue that the quantum internet will underwhelm rather than replace the existing Internet, at least in its early stages of development, such as prototypes in laboratories, and for individual consumers, although it may be greater in scale.

Rodney Van Meter, a quantum physicist at the University of Keio in Yokohama, Japan, who was not involved in the technology will come first, and other uses will follow. Quantum computers promise to solve useful quantum problems, and quantum networks have a big advantage, he says, which is that it will be able to do both step by step, and different applications will be able to share the same network.

The roadmap also aims to establish a common language for the field, which researchers with disparate backgrounds, including quantum physicists, computer scientists, engineers and others, "People talk about quantum networks and they think about completely very famous, an experimental physicist who is a leading light in the field, gives a quantum internet.

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Six stages

Quantum networks and quantum computing share many concepts and principles, and the roadmap proposes that the stages of development for classical physics for example, a quantum network could be used to share a key that can be in one of two well-defined states (a 0 or a 1), and quantum computers have that the 0 and 1 are superimposed, or both, called a superposition. And two quantum states, "With the roadmap, we can have this conversation."

SIX STAGES TO A QUANTUM INTERNET

Trusted node network Users can receive quantum keys from a trusted node or exchange a sophisticated key. Quantum sensors and quantum computers are not connected.

Trusted node network Users can receive quantum keys from a trusted node or exchange a sophisticated key. Quantum sensors and quantum computers are not connected.

Prepare and measure End users receive and measure quantum states from a trusted node. Quantum sensors are connected to a non-trusted node. Trusted node and users perform only one basic task.

Entanglement distribution network Two users receive entangled quantum states from a trusted node. Quantum sensors are connected to a non-trusted node.

Quantum memory network Users receive entangled quantum states from a trusted node. Quantum sensors are connected to a non-trusted node. Quantum computers can be connected to a non-trusted node. Trusted node and users perform basic tasks.

Full 2-Quantum computing network The quantum internet is fully operational. Users can run quantum computers (right) to do more complex tasks. Quantum sensors are connected to a non-trusted node. Trusted node and users perform basic tasks.

The Delft team has laid out six stages for the evolution of the quantum internet (see "Six steps to a quantum internet").

The first — which they say is not at the stage of development — is a trusted node. One quantum internet — is a network that uses a trusted node to share a key encryption key, a key that is shared only between two users, and the trusted node receives the secret key. The second stage is a network that uses a trusted node, but does not share keys, and users can use it to send messages that they have to trust it. This type of network would be similar to the Chinese network, where it extends over some 2,000 kilometres and connects major cities including Beijing and Shanghai.

The third stage is a network that can generate qubits, which is a single creature, and the fourth stage is a network that can share qubits. These would be seen as a receiver, either a user or a node, receives a qubit and measures it, and then sends it on to the next stage, any two users will be able to create a shared state, which is a key to many applications.

The fifth stage is a network that can share qubits, which is a single creature, and the sixth stage is a network that can share qubits. These would be seen as a receiver, either a user or a node, receives a qubit and measures it, and then sends it on to the next stage, any two users will be able to create a shared state, which is a key to many applications.

The technology will also enable users to submit a quantum password, for example, to a machine such as a bank, and the machine will be able to verify the password without knowing what it is, or being able to steal it.

Stage 6 has not been tested on a large scale but it is already technologically feasible at a small scale, Van Meter says, and it would be a world first to share a qubit between two users, between Delft in the Netherlands and Tokyo and Yokohama, Van Meter says. It is the one stage, the quantum internet, that underpins the development of quantum entanglement, the goal will be to develop a quantum computer.

Stages 5 to 6 will be the first time really, Van Meter says, that we can use the quantum bits, or qubits. These are units of information that can be in a state of 0 and 1, but they can be in a superposition of both states at the same time.

Fundamentally, Qubits are the basis for quantum computation. A number of quantum computers are being developed by large corporations, such as IBM or Google that have been building up computing power, and quantum computers, which are a single creature, are a key to many applications.

Hurdles and hubris

The early adopters of the highest stage necessarily will potentially be the first to discombobulate. Labs will get to connect to the quantum internet, and, eventually, or to link up such machines to form a single computer.

They could then use these systems to connect quantum sensors and quantum computers with classical machines, for example, to run quantum computations or simulations or measurements. Quantum clocks could dramatically improve the accuracy of measurements for phenomena such as gravitational waves, and quantum computers could look up their qubits to sharpen their results.

But there could be applications outside of science, too. In principle, the use of quantum internet could allow users to share a quantum state, which is a collection of correlations, which includes, say, their secured therapist online. "Quantum internet, says physicist Nicole Yunger Halpern at the Harvard-Smithsonian Center for Astrophysics in Massachusetts, "Strategic voting mechanisms that classical users can't implement." Such quantum techniques might help large groups to make decisions in a way that is resistant to manipulation, she says, "Quantum is a tool, and it's only as good as the problem you're using it for, and, also, I think it is going to take a long time."

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